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# (54) Optical weld seam tracker

(57) A method and apparatus for simultaneously tracking and welding a seam(14) between two workpiece portions (28, 30). Light from a light source (10) is focussed onto a portion of the weld seam lying closely adjacent to the welding torch (24). The reflected image from the illuminated portion of the seam is detected by a t.v. camera, whose picture is scanned and digitized. The resulting digital information is used by a controller (20) to compute the position of the next portion of the seam to be welded and to which the torch is to be moved.

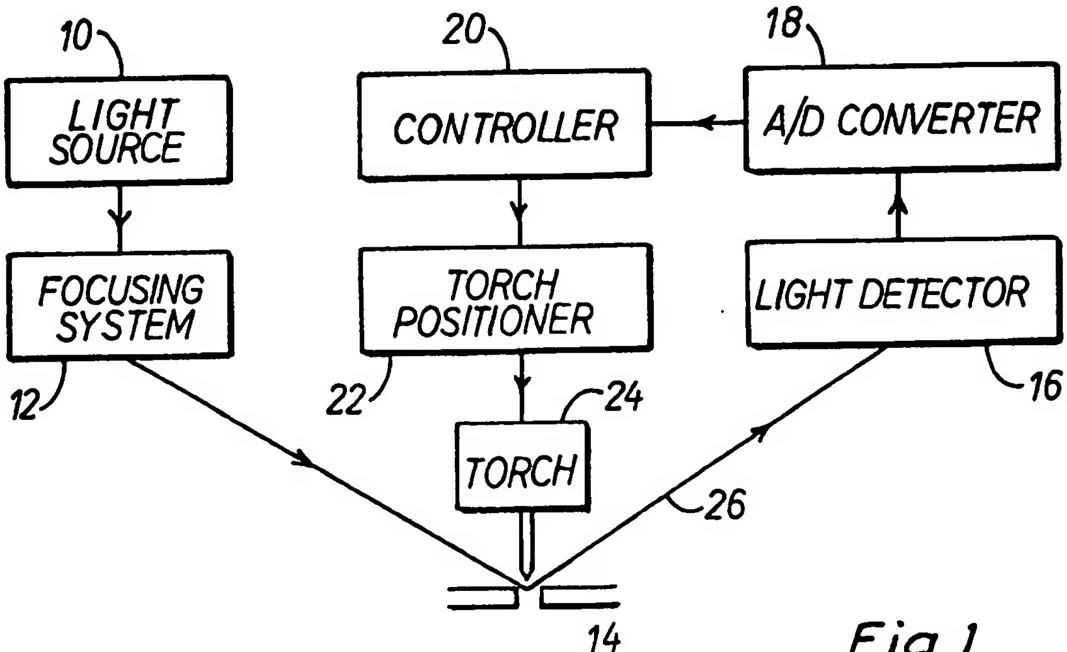


Fig 1

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The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

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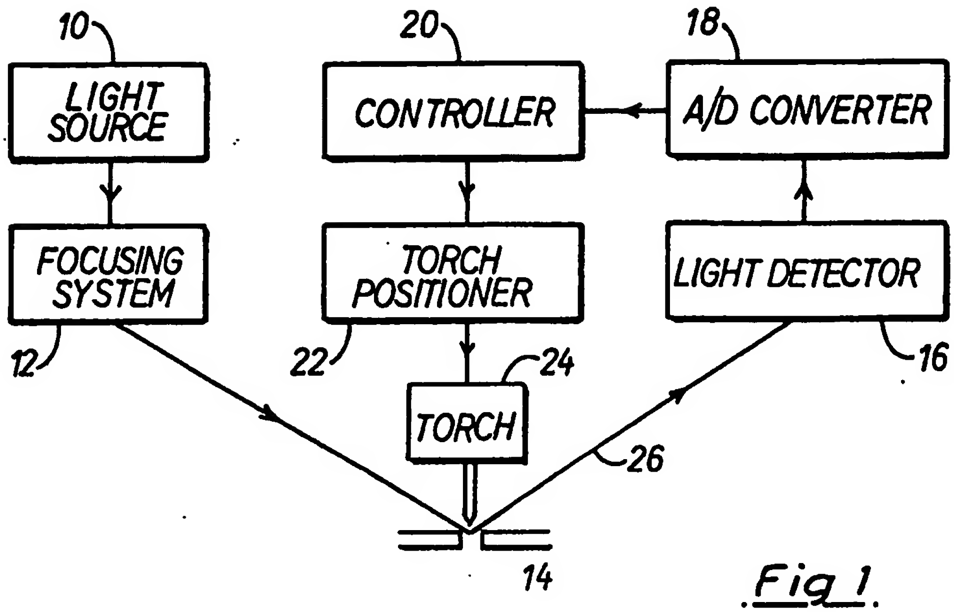



Fig 1.

Fig 2

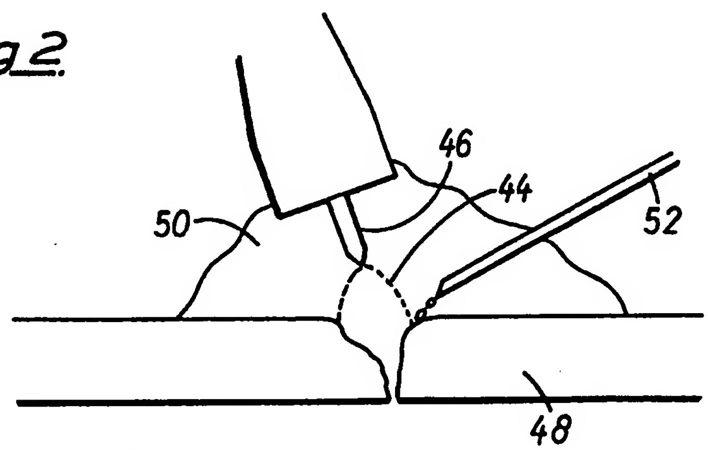



Fig 3a

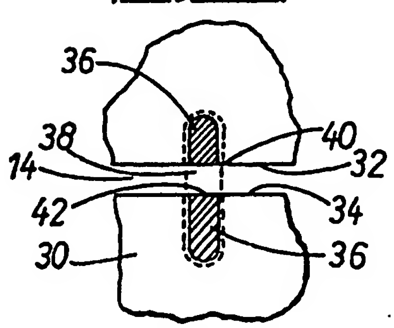
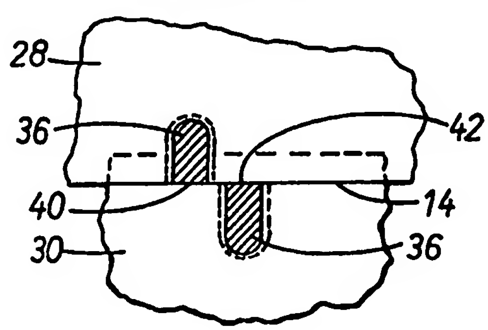



Fig 3b.



## SPECIFICATION

### Optical weld seam tracker

The present invention resides in an optical weld seam tracker.

The growth of industry relies upon the continuing development of processes and materials. In the field of welding this has meant a need for quicker, more reliable welding methods for use in, for example, the automotive industry where production runs are usually long but where great precision is not always required, and in high precision engineering where production runs are often short but the precision components require much higher quality welds. Welding processes have been developed specifically to suit these different demands. For example, the M.I.G. (metal inert gas) process is used for less demanding tasks whereas the T.I.G. (tungsten inert gas) process is especially suited to tasks requiring a greater degree of accuracy.

Of course, some welding tasks are best done manually, in the shipbuilding industry for instance, but many can be performed automatically using robotic control systems. Such systems are known in which the welding seam is first tracked out, the co-ordinates of the seam path being stored in the memory of a computer which then controls the welding apparatus to retrace and weld the seam. Thus, in these systems the seam has to be followed twice for every welding operation.

It is an object of the present invention to provide a weld seam tracker which overcomes the above disadvantage of double tracking.

The term "seam" or "weld seam" as used herein refers to a junction between two metal members which are to be welded together but before the weld is actually made.

In accordance with a first aspect of the invention there is provided a method of simultaneously tracking and welding seam, comprising displacing a welding torch in a first direction generally parallel to the length of the seam to be welded, illuminating a portion of said seam lying adjacent to said torch, detecting the reflected image from said portion of the seam, sensing and computing the position of said portion of said seam in the reflected image, and displacing the torch in a direction perpendicular to said first direction so as continuously to align the torch with said seam.

In accordance with a second aspect of the present invention there is provided apparatus for simultaneously tracking and welding a seam comprising a welding torch, means for displacing the torch in a first direction which, in use, is arranged to be generally parallel to the length of a seam to be welded, means for illuminating a portion of said seam lying adjacent to said torch, means for detecting the reflected image from said portion of the seam, means for sensing and computing the position of said portion of said seam in the reflected image and means for displacing the torch in a direction perpendicular to said first direction to continuously align the torch with the seam.

In accordance with a third aspect of the present invention there is provided a method of simultaneously tracking and welding a seam comprising illuminating a first part of the seam, detecting the reflected image of said first part of said seam, sensing and computing the position of said first part of said seam in said reflected image, moving a weld torch to said first part of said seam and then welding said first part of said seam, sequentially illuminating further, contiguous parts of said seam, and moving said weld torch to said further parts of said seam in response to the computer positions thereof.

The invention will be described further hereinafter, by way of example only, with reference to the accompanying drawings, in which:

*Figure 1* is a block diagram of one embodiment of a weld seam tracker of the present invention;

*Figure 2* shows the basic components of a T.I.G. weldong process; and

*Figures 3a and 3b* show various reflected images from a weld seam.

The salient features of an optical weld seam tracker of the present invention are shown in Fig. 1. Light from a light source 10 is passed through a focussing system 12 and onto an area of metal defining part of a weld path 14, the weld path being defined normally by the adjacent or abutting edges of two pieces of metal which are to be joined by a welded seam. The reflected light is picked up by a light detector 16 and the received image scanned and digitised by an analog to digital converter 18. This information is then fed into a controller 20 which works out the position of that portion of the weld path 14 and which then uses the information to control a torch positioner 22 which moves a welding torch 24 onto that part of the weld path which has been detected. The torch positioner acts effectively to displace the torch in a first direction generally parallel to the length of the seam to be welded and in a direction perpendicular to said first direction so as continuously to align the torch with the position of the seam as determined by the controller 20 from the scanned image. The torch 24 is kept as close as possible to and behind the illuminated part of the weld path 14. In this way, when the torch 24 welds a first part of the weld seam, the detecting system determines the position of a second part of the weld seam immediately ahead of and adjoining the first part and then moves the torch 24 into position to weld this second part. These steps are repeated until the whole weld seam has been welded.

In a preferred embodiment, the light source

10 is a tungsten halide lamp. The light from this is passed into a series of lenses in the focussing system 12. The light source and focussing system are fixed on a mounting frame (not shown) along with the torch 24 and are placed as close as possible to the torch 24 so that the light hits the weld-path 14 just ahead of the torch and almost to the edge of a molten weld pool which is formed near the tip of the torch electrode during welding.

A fibre optic cable, indicated at 26, picks up the reflected light from the weld path 14. The end of the fibre optic cable which receives the reflected light is also mounted close to the torch 24 and is positioned in the path of the reflected light. The use of fibre optics reduces electrical interference from the arc, formed by the torch 24, to the controller 20 to a negligible amount. It is also possible to use a fibre optic cable to transmit the light from the light source 10 to the weld path 14, thus enabling the light source to be remote from the torch mounting.

The light intensity required from the light source depends, to a large extent, on the light given off by the arc during welding and on the light reflected from the molten weld pool. It is essential that the intensity of light received by the detector 16 from the light source 10 should be much greater than that from the arc and weld pool. This is because when light is shone onto a weld path, light is only reflected from the surrounding metal and the reflected image contains a shadow corresponding to the weld path. If the detector receives light from another source, then this other source might fall on the shadow image making the shadow less distinctive and harder to distinguish from the surrounding light areas.

In the present embodiment the required light intensity is achieved by using a high intensity tungsten halide lamp for the light source 10. Also, the torch 24 is positioned so that at least part of the light from the arc and weld pool is blocked from the view of the detector 16. Separate baffles can be provided to reduce the light from the arc and weld pool reaching the detector 16. Thus, when light from the light source 10 is corectly focussed onto the weld path 14, the detector 16 receives a distinctive image of the weld path 14 and its surrounding metal surface. The light detector 16 used is a standard television camera. With this, optical filtering is necessary because the combined intensity of light from the light source 10 and the arc would "blind" the camera. The filtering device is fitted at the end of the fibre optic cable which receives the light and comprises a neutral density filter which acts by reducing the intensity of light across the whole wavelength range. As an alternative, a band pass filter could be used in which only light of a specific wavelength (preferably corresponding to that wavelength which has the greatest light intensity from the light source) is transmitted to the camera. Equivalently, a monochromatic light source, such as a sodium lamp, or a laser could be used to replace the light source and filtering device.

Once the reflected light is received by the camera, the picture is scanned and digitised by the A/D converter 18. This senses the intensity of light from each part of the picture and grades it according to intensity. In the preferred embodiment, an arbitrary scale of one to ten is chosen, one being darkest, ten being lightest. Anything below and including five is deemed dark and anything above five is deemed light.

The above-described optical system has proved efficient enough that most areas of the image are sensed as being virtually light or virtually dark with very few in-between areas. In this way, a clear black and white digital picture is built up, the black parts indicating a shadow and hence the weld path and the white parts indicating the surrounding metal. The position of the shadow within the reflected image indicates the position of the next part of the weld path to be welded and hence the position to which the torch must be moved by the positioning system 22.

Figs. 3a and 3b show two possible configurations of the weld seam 14. In Fig. 3a, two metal plates 28, 30 are placed as close together as possible, their adjacent edges 32,34 then defining the required weld path 14. Light is shone onto the plates in an area shown by the dotted line. The image then received consists of light areas 36 (shown darkened for convenience) and a dark area 38 defining part of the weld path 14 (shown lightened for convenience). In Fig. 3b, plate 28 is placed over plate 30. This produces two light areas 36 displaced from one another due to the height difference between the two surfaces and the angle from which the light is shone. The edges 40,42 of the light areas define the border of the dark areas and thus the path of the weld seam 14.

Having detected and digitised these images, the information is then fed into the controller 20 which is a microprocessor-based control system. The micro processor is programmed to compute the co-ordinates of the edges 40,42 which define the weld path shadow, from the information given by the digital pictures. A control signal is then sent to the torch positioner 22 which moves the torch to the computed co-ordinates where it then welds the seam. The torch positioner 22 is a system of robotics which permits movement in three dimensions to allow for a variation in the contour of the metal surfaces. The controlling of height adjustment is dependent upon the type of welding process used. The present invention has been developed for use in the

high accuracy T.I.G. process but can be equally adapted to suit the M.I.G. process or plasma welding or most other types of welding.

In the T.I.G. process, as shown in Fig. 2, an arc 44 is formed between a pointed tungsten electrode 46 and the workpiece 48 in an argon or helium atmosphere 50. Filler material 52 is added separately in wire form. This is contrary to the M.I.G. process which uses a consumable central electrode as the filler material. In order to monitor the height of the electrode from the workpiece a separate voltage/current control system is required in which the voltage between the electrode and workpiece is measured. If the distance is changed the effective arc resistance changes and so the measured voltage changes. This change in voltage causes a signal to be sent to the controller 20 which computes the change in distance and then sends a control signal to the torch controller 22 to accordingly change the distance to its original value. Hence the electrode is kept at a substantially constant height from the workpiece. Because the focussing system 12 is mounted with the torch 24, no other adjustment is necessary for focussing.

An advantage of using the present invention in conjunction with the T.I.G. welding process is that the whole welding apparatus, including the torch, the light source and focussing system and the separate wire feed, can be detachable from a particular robot and attached to another robotic system more suited to a particular application.

Applications using the T.I.G. process require a great degree of accuracy. For instance a typical weld pool is 2 to 5 mm in width and must be tracked precisely along the seam to an accuracy within the range 0.05 to 0.2 mm. The electrode to workpiece distance, in which the arc length is typically 2 to 3 mm, is required to an accuracy better than 0.1 mm. Accuracy of this degree can be met by the present invention which provides a highly accurate, automatic welding system, paritcularly suited to the high demands of T.I.G. welding.

## CLAIMS

1. A method of simultaneously tracking and welding a seam comprising displacing a welding torch in a first direction generally parallel to the length of the seam to be welded;

illuminating a portion of said seam lying adjacent to said torch;

detecting the reflected image from said portion of the seam;

sensing and computing the position of said portion of said seam in the reflected image; and

displacing the torch in a direction perpendicular to said first direction so as continuously to align the torch with said seam.

2. A method as claimed in claim 1 wherein the position of the seam is determined by detecting the position within the reflected image of the relatively dark line or dark area caused by the seam between two relatively light areas established, as a result of said illumination, on the workpiece regions defining the two sides of said portion of the seam.

3. An apparatus for simultaneously tracking and welding a seam comprising a welding torch, means for displacing the torch in a first direction which, in use, is aranged to be generally parallel to the length of a seam to be welded, means for illuminating a portion of said seam lying adjacent to said torch, means for detecting the reflected image from said portion of the seam, means for sensing and computing the position of said portion of said seam in the reflected image and means for displacing the torch in a direction perpendicular to said first direction to continuously align the torch with the seam.

4. An apparatus as claimed in claim 3 wherein, said illumination means comprises a light source and said detecting means comprises a light detector, said light source and light detector being coupled to the torch for movement therewith.

5. An apparatus as claimed in claim 3 wherein, said illumination means includes a fibre optic cable whose one end receives light from a light source and whose other end is disposed so as, in use, to direct a beam of light onto a seam to be welded.

6. An apparatus as claimed in claim 5 wherein, at least said other end of the fibre optic cable is coupled to the torch for movement therewith.

7. An apparatus as claimed in claim 6 wherein, the detecting means comprises a light detector, also coupled to the torch for movement therewith.

8. An apparatus as claimed in claim 6 wherein, the detecting means includes a light detector disposed at one end of a further fibre optic cable, at least the other end of said further fibre optic cable being coupled to the torch for movement therewith.

9. An apparatus as claimed in any of claims 3 to 8 wherein, the light source provides monochromatic light.

10. An apparatus as claimed in any of claims 3 to 9 including means for optically filtering the reflected image upstream of said detecting means.

11. An apparatus as claimed in claim 10 wherein, said optical filtering means is a neutral density filter.

12. An apparatus as claimed in claim 10 wherein said optical filtering means is a band pass filter.

13. An apparatus as claimed in any of claims 3 to 12, including means for mechani-

cally shielding the illuminated portion of the seam from light emitted, in use, by the weld itself.

14. An apparatus as climed in any of claims 3 to 13 wherein, said sensing and computing means includes a t.v. carera for receiving the reflected image, means for scanning and digitizing the picture of the reflected image generated by the t.v. camera and a computer for operating on the resulting digital information to compute the position of the next portion of the seam to be welded.

15. An apparatus as claimed in any of claims 3 to 14 including means for monitoring the height of the torch above the seam being welded and a means for automatically maintaining the height above the seam at a predetermined magnitude.

16. A method of simultaneously tracking and welding a seam comprising illuminating a first part of the seam, detecting the reflected image of said first part of said seam, sensing and computing the position of said first part of said seam in said reflected image, moving a weld torch to said first part of said seam and then welding said first part of said seam, sequentially illuminating further, contiguous parts of said seam, and moving said weld torch to said further parts of said seam in response to the computed positions thereof.

17. A method of simultaneously tracking and welding a seam, substantially as hereinbefore described with reference to the accompanying drawings.

18. An apparatus for simultaneously tracking and welding a seam substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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